

## II.4-SARROUTE SSARR CHANNEL ROUTING

### Introduction

This Chapter describes the SSARR channel routing method used in Operation SARROUTE which is based on the Streamflow Simulation and Reservoir Regulation System (SSARR) model developed by the North West River Forecast Center and the North Pacific Division of the US Army Corps of Engineers.

This method allows considerable flexibility to determine routing coefficients which simulate downstream peaks and timing response.

The time rate of change of streamflow in a river reach is evaluated by first dividing the reach into a series of increments or a 'chain of lakes'. The routing method for each of the 'lakes' is described by:

$$O_2 = O_1 + t * (I_m - O_1) / (TS + t/2)$$

where  $O_1$  is the outflow at beginning of period  
 $O_2$  is the outflow at end of period  
 $t$  is the time duration of computational period  
 $TS$  is the time of storage  
 $I_m$  is the mean inflow

Outflow from each increment is used as inflow to the next downstream increment and the step-by-step procedure completed for each increment for each time period. Outflow routed through three such successive increments is illustrated in Figure 1. Begin and end increment inflows are required to determine the mean inflow of the time increment. The end increment outflow which is used by the next increment as inflow is returned by the routing routine is computed to conserve the inflow hydrograph volume as we move along the routing reach.

Time of storage for channel routing increments may be specified in a table of time of storage versus discharge (for such cases as overbank routing) or may vary inversely or directly as a power function of discharge. Normally when flows are confined to the channel the time of storage decreases as discharge increases and it is convenient to express the relation from the following equation:

$$TS = KTS/Q^{*n}$$

where  $TS$  is the time of storage per increment in hours  
 $KTS$  is the a constant determined by trial and error or estimated from physical measurements of flow and corresponding routing times  
 $Q$  is the discharge in CFS  
 $n$  is the a coefficient usually between -1 and 1

By taking the log of both sides of this equation the equation becomes:

$$\log TS = \log KTS - n \log Q$$

Figure 2 can be used to estimate n for a given reach if the average discharge for the reach is known and an KTS value has been selected.

The number of routing phases specified for a channel significantly affects the peak and timing response of the hydrograph (Figure 3). As the number of phases increases with all other factors constant the peak decreases and the total time of storage increases.

The KTS and n parameters of the routing equation can be manipulated to obtain the desired time of storage per phase (TS). KTS affects the time of storage linearly as indicated by the routing equation:

$$TS = KTS/Q^{*n}$$

This equation is illustrated graphically in Figure 4 and Figure 5 for a positive and negative n. Larger values of KTS result in longer time of storage for a given number of phases (Figure 6).

The n coefficient relates flow to time of storage exponentially with smaller values of n yielding much greater time of storage for a given KTS (Figure 7). In this case time of storage is related to discharge inversely. However in some basins time of storage varies proportionally to discharge (Figure 8). As illustrated with negative n values the time of storage is extremely sensitive to slight changes in value of n.

#### Determining SSARR Routing Characteristics for a Reach

The routing parameters for a given channel reach are usually determined as in the following example:

- o Assume an n value - in this case assume n = 0.20
- o Determine the total time of storage for the reach. This equals approximately the time travel for the reach. For this example the total time of storage is approximately 48 hours.
- o Determine the number of routing phases to be used. Larger number of phases results in less attenuation of the hydrograph peak given a fixed total time of storage. The number of phases are ultimately determined by trial; however for initial trials the number of phases can be estimated by assuming 5 to 10 miles of channel per phase. Once the number of phases is determined, divide the total time of storage by the number of phases to obtain the time of storage per phase.
- o From the routing equation as illustrated in Figure 4 find the value of KTS corresponding to TS, n and a discharge of 35,000 CFS. In this example for n=0.2, the total time of storage of 48 hours and using 4 routing phases KTS would equal 96. Once an initial trial is made KTS, n and the number of phases can be easily adjusted to improve reconstructions. The variability of the routed hydrograph with number of phases assuming total TS is constant is shown in Figure 9. A similar example but with n=0.4

is shown in Figure 10. By comparing the two figures it is clear that  $n$  is relatively insensitive when a specific total time of storage is desired. The larger  $n$  value results in a slightly greater non-linearity which results in greater variability in the routed hydrographs.

#### Discharge-Time of Storage Table Alternative

The user has the alternative to define a specific discharge-time of storage relationship for a channel reach. Such a table enables a precise definition of relationships and can be used to simulate rather unique or unusual channel routing changes with discharge. Figure 11 illustrates the use of three different routing-discharge relationships. Hydrograph 4757 shows the effects of TS decreasing as discharge increases. The inverse is true of station 4787.

A typical relationship for overbank flows is illustrated by station 4797. Here TS decreases as flow increases up to the bank full point of about 20,000 CFS. After bank full is reached TS increases because of the overbank condition. As flow increases to 26,000 CFS the flood plain becomes inundated and TS values become constant with additional flow. Complex routing-time of storage relationships can be defined for cases of flood flows when adequate information is available.

#### Short Time of Storage Computations

Within the program reach computations the routing characteristics are determined mainly by the time of storage value TS. TS is computed for each routing period at each reach routing station. Whenever the computed value of TS falls below the value of half of the routing period the program automatically breaks the current routing period into two more sub-periods so that the sub-periods will never be longer than twice the TS value.

Figure 12 illustrates how the computations are made for a simple single phase routing assuming a computation period of 6 hours, a constant TS with flow of 2 hours and a single phase routing. Figure 12 shows the equations and computations when the routing period is kept at 6 hours versus when the routing period is split to 2 hours. A new average inflow for each of the subdivided periods is computed. The average inflow is based on the interpolated flows for the start and end of the subdivided period. Figure 13 shows a plot of the start period inflow hydrograph (I1) and the non-subdivided (NS01) and subdivided (SUB01) start period outflow hydrographs.

#### Reach Carryover Values (Initial Conditions)

The carryover values needed to specify reach initial conditions is the instantaneous initial start of period inflow and the routing phase values. The instantaneous initial start of period inflow is specified through the start of period inflow time series when both the start and end of period inflow time series are specified. In the case where

only the end of period inflow time series is specified the instantaneous initial start of period inflow is specified through input card number 5. The first phase flow value is the initial end of period outflow. All carryover values must be specified on input.

#### References

SSARR Model: Streamflow Synthesis and Reservoir Regulation, U.S. Army Corps of Engineers, North Pacific Division, January 1991.

Figure 1. Outflow routed through three successive increments

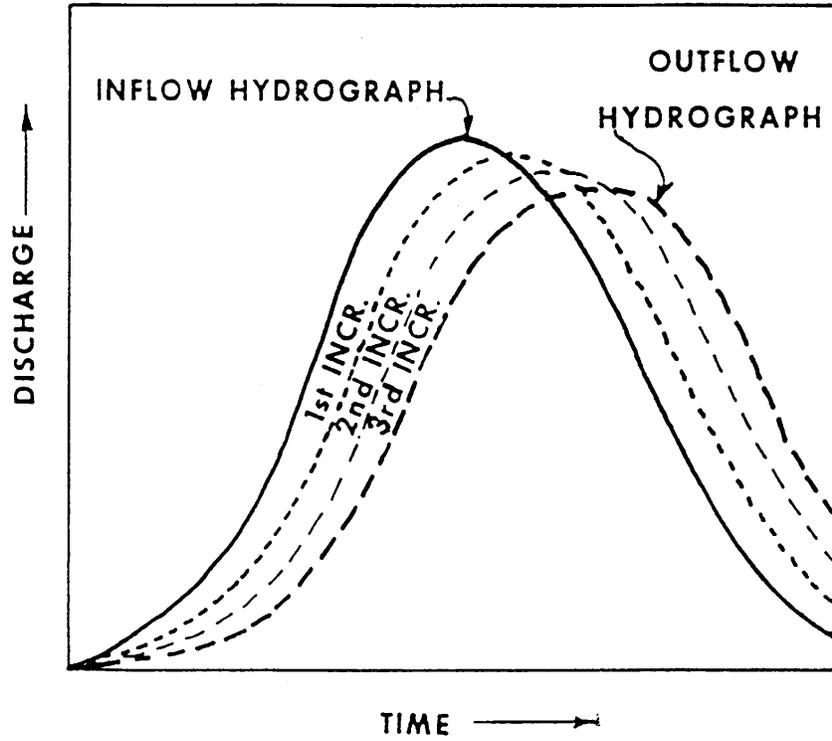


Figure 2. Relationships between KTS, discharge (Q) and N values for KTS equal to 100

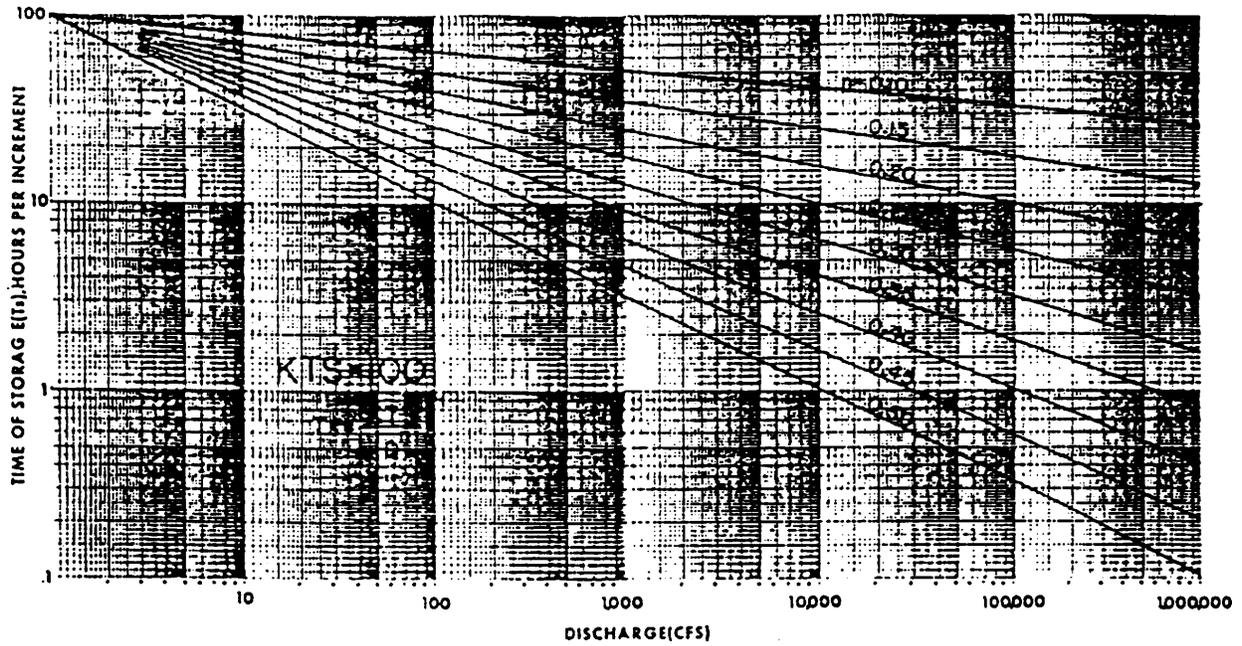


Figure 3. Effect of varying the number of routing phases with the channel routing equation

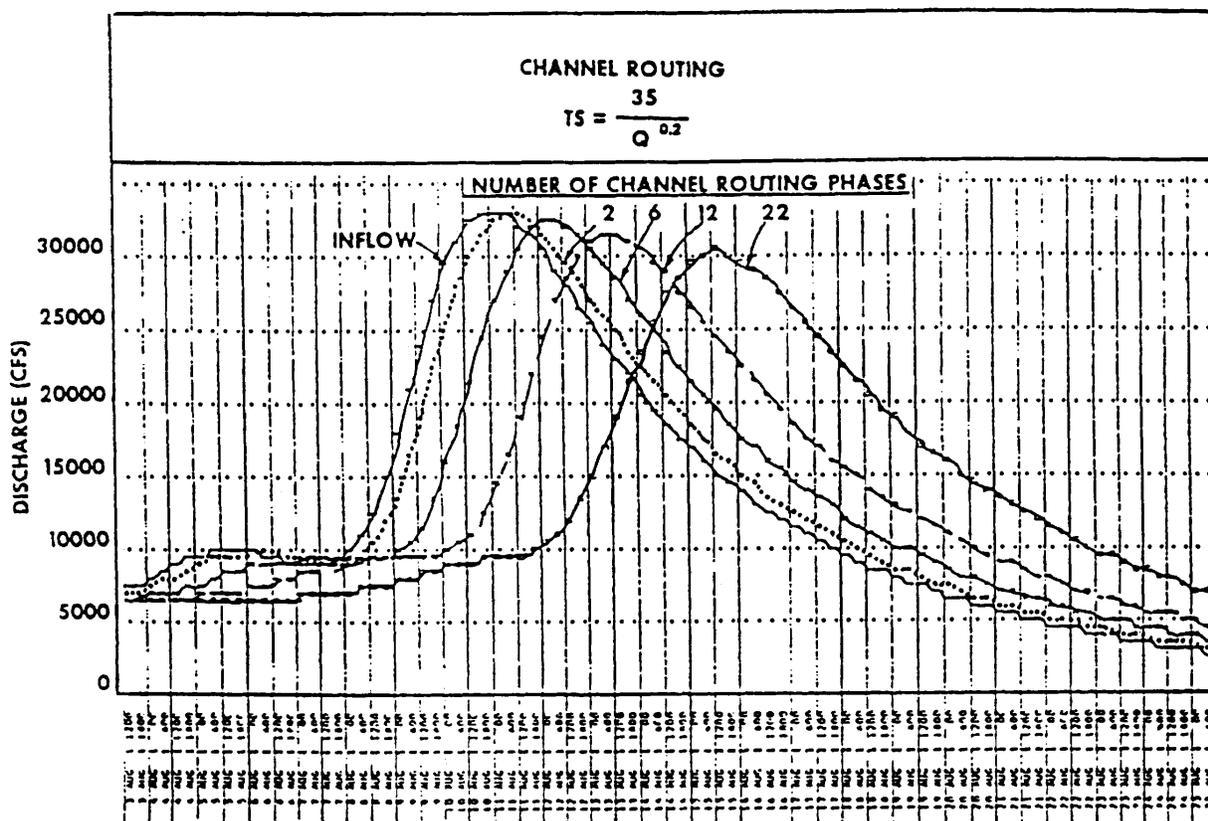


Figure 4. Relationships of KTS, discharge (Q) and time of storage per phase for the channel routing equation

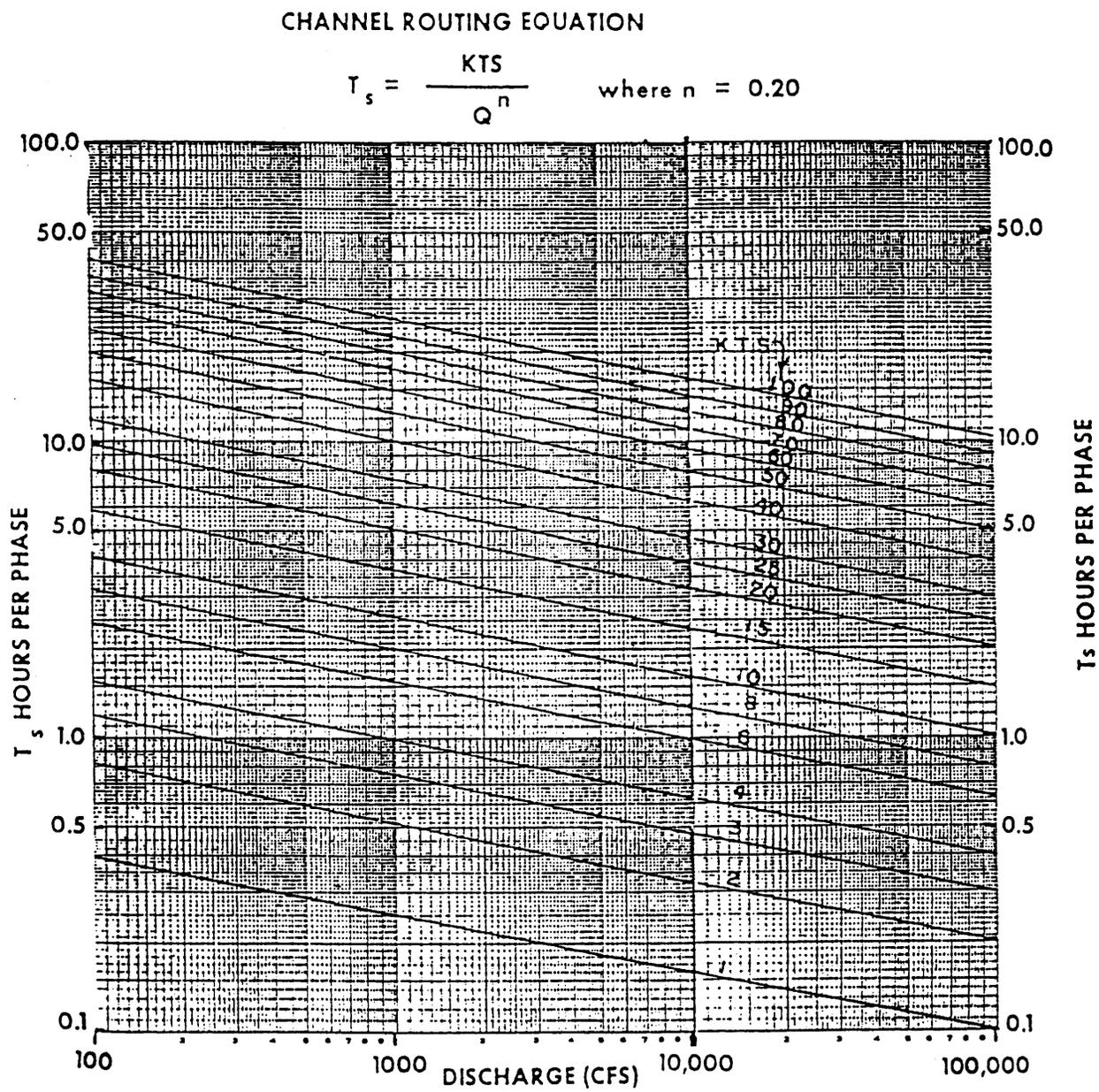


Figure 5. Relationships of a negative n, KTS, discharge (Q) and time of storage per phase (T<sub>2</sub>) for the channel routing equation

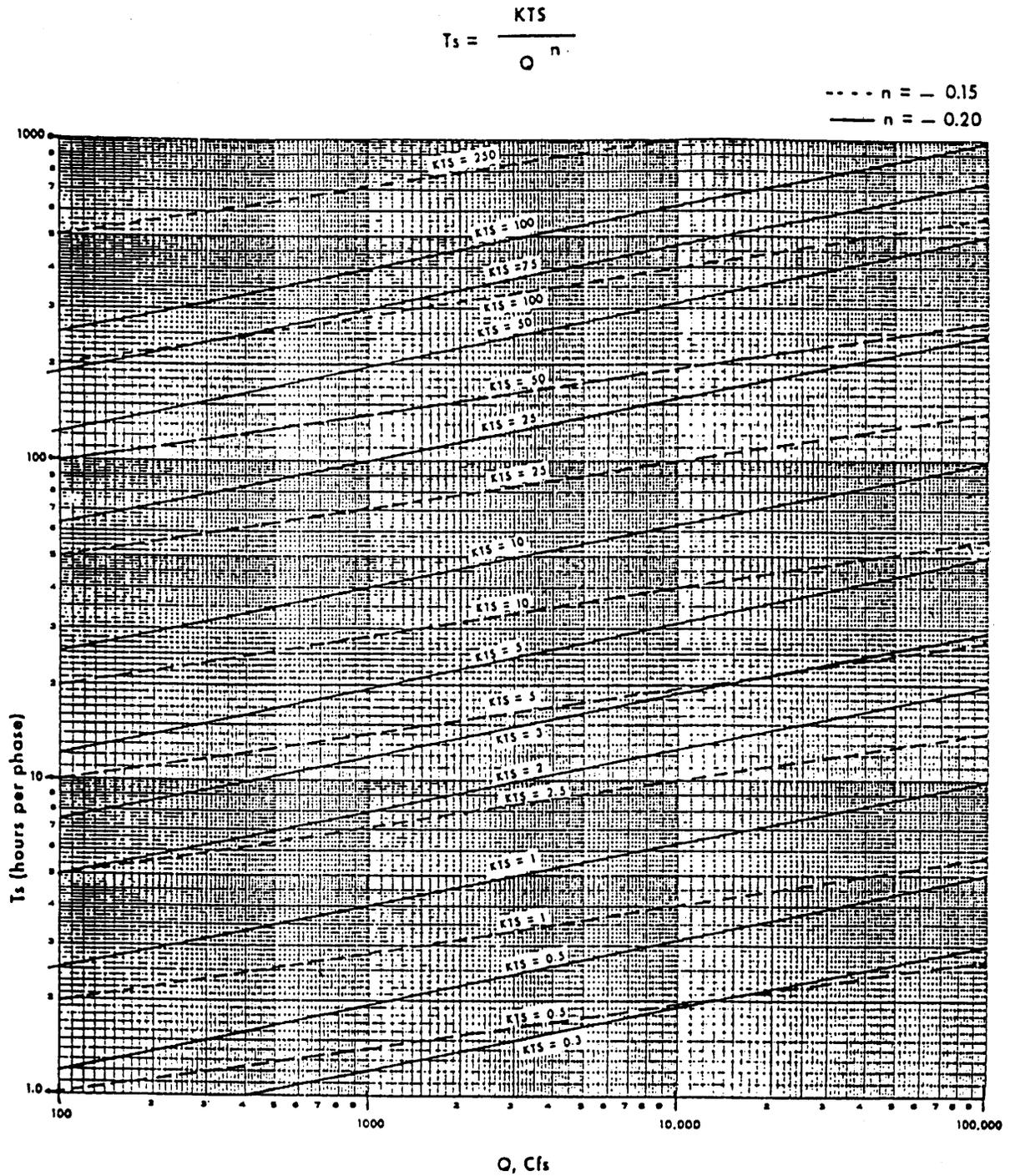


Figure 6. Effects of varying KTS in the channel routing equation

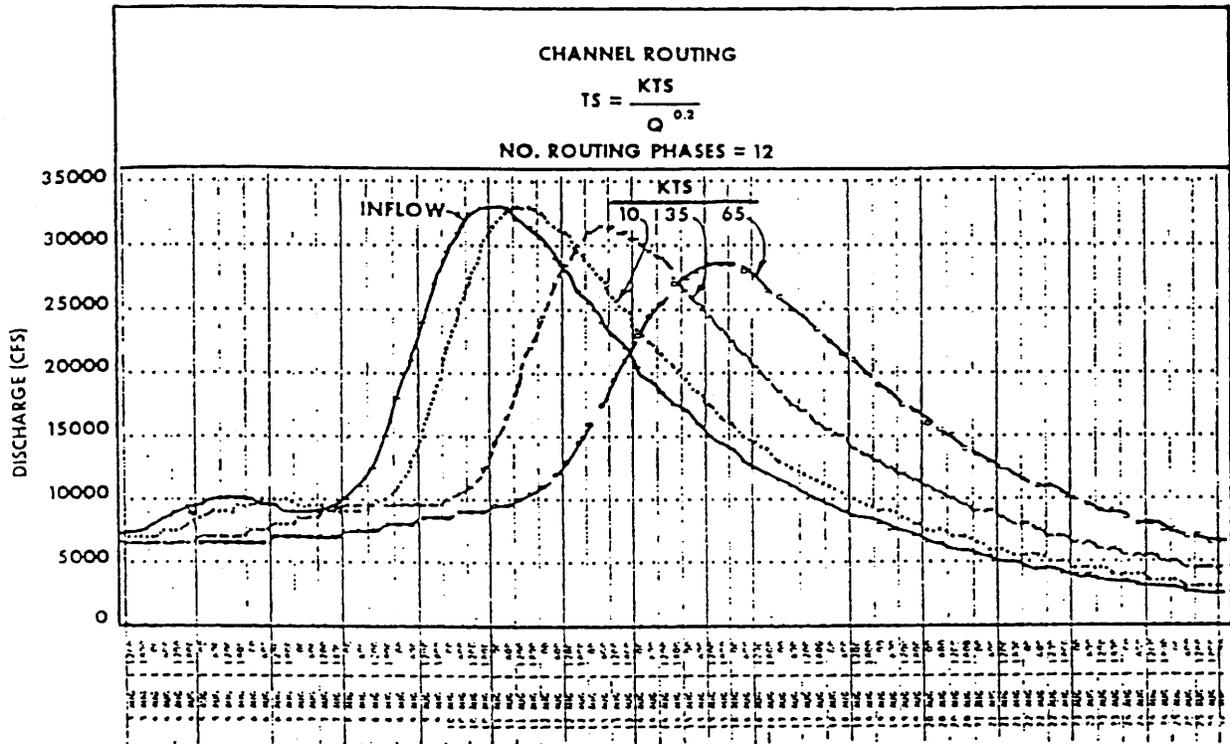


Figure 7. Effects of varying the n in the channel routing equation

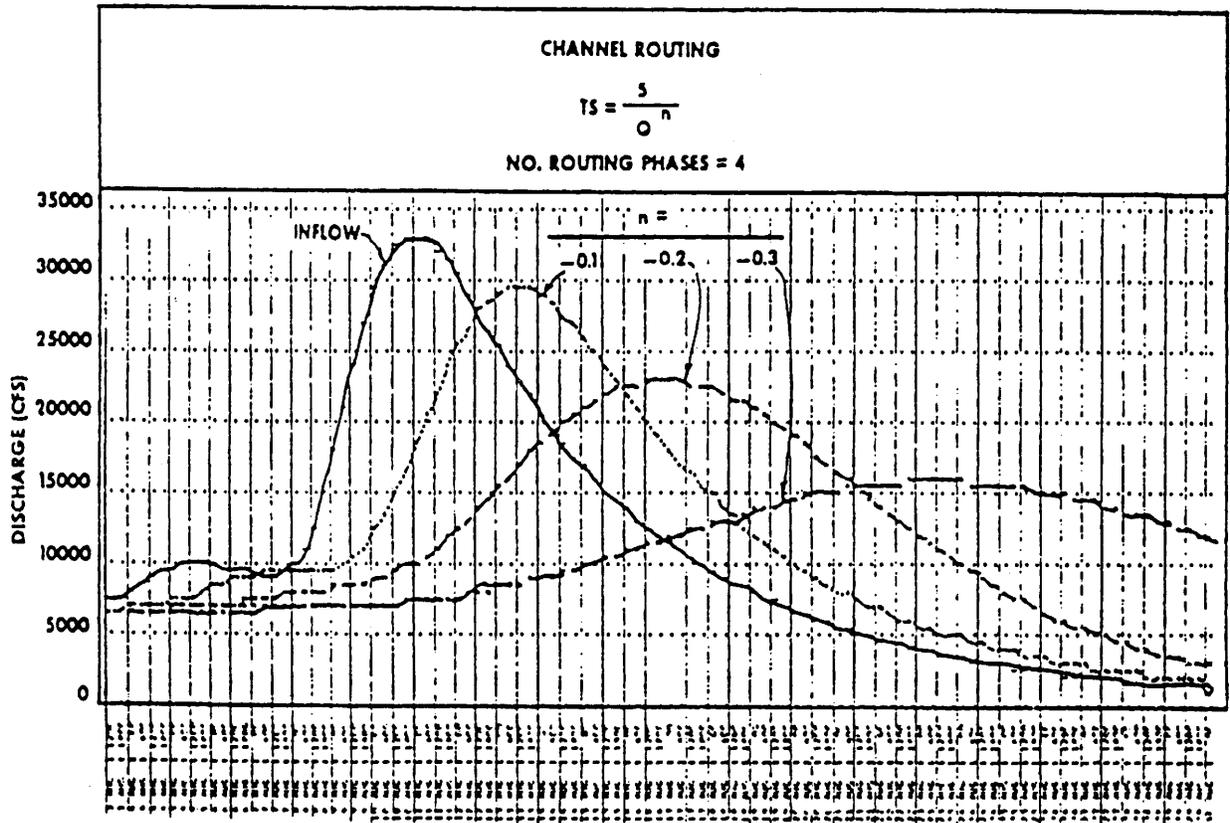


Figure 8. Effects of varying negative n in the channel routing equation

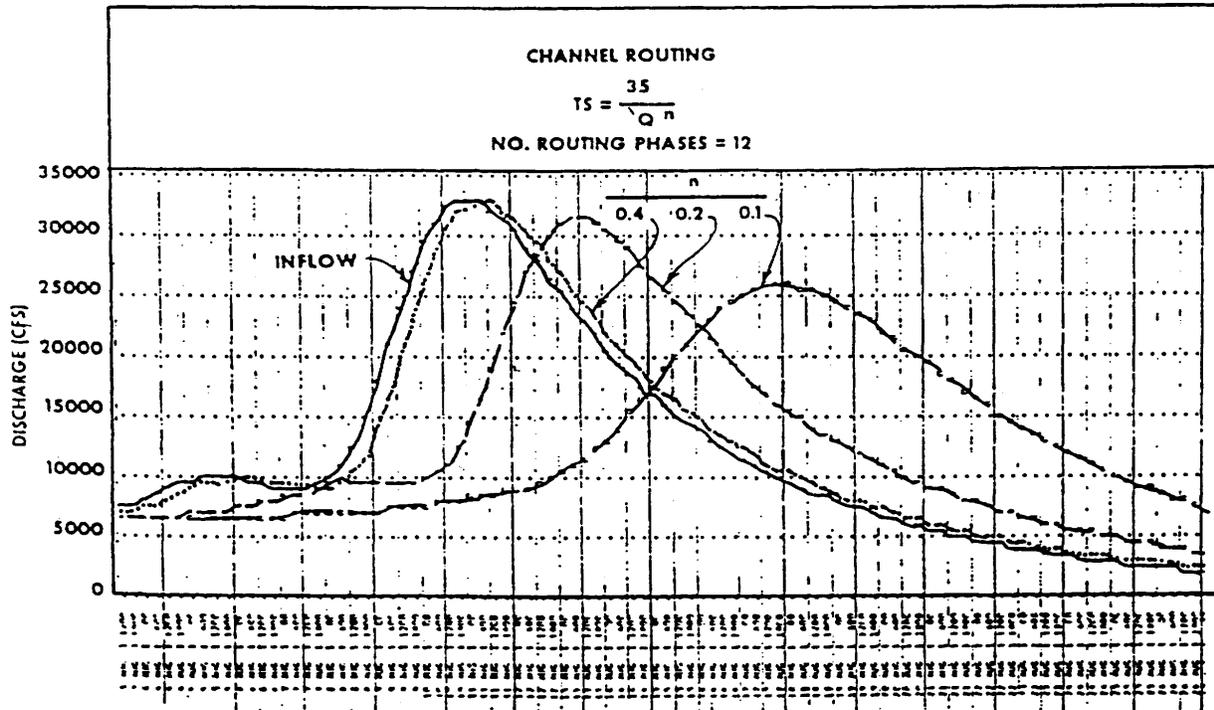


Figure 9. Example of various routing characteristics for a channel reach with a specific time of storage

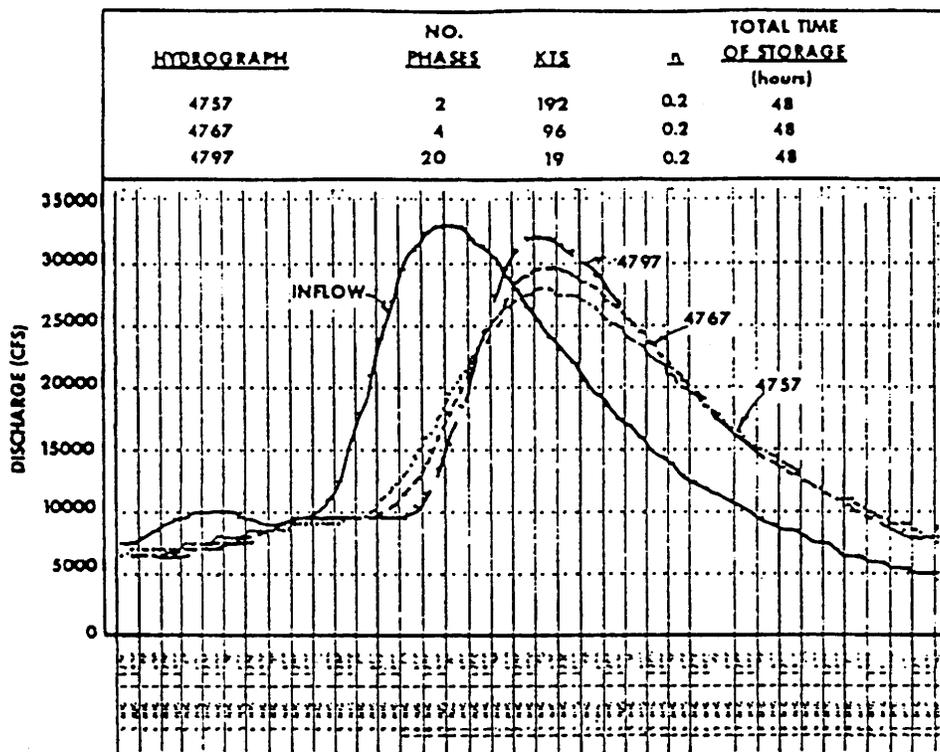


Figure 10. Routing characteristics of a channel reach with a given total time of storage

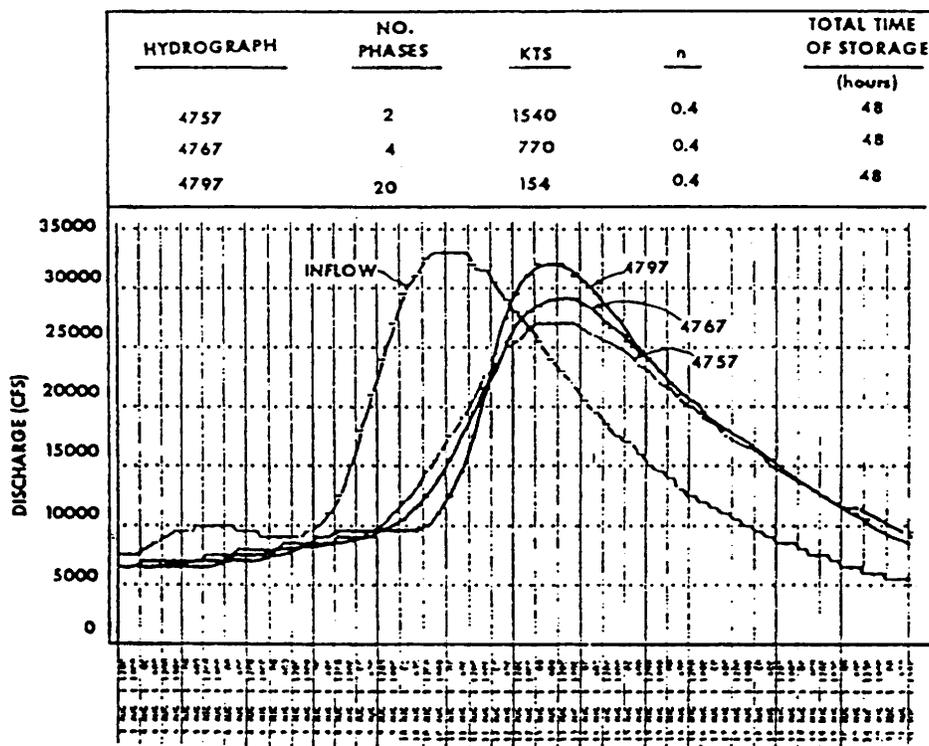


Figure 11. Examples of the use of routing to characterize channel routing

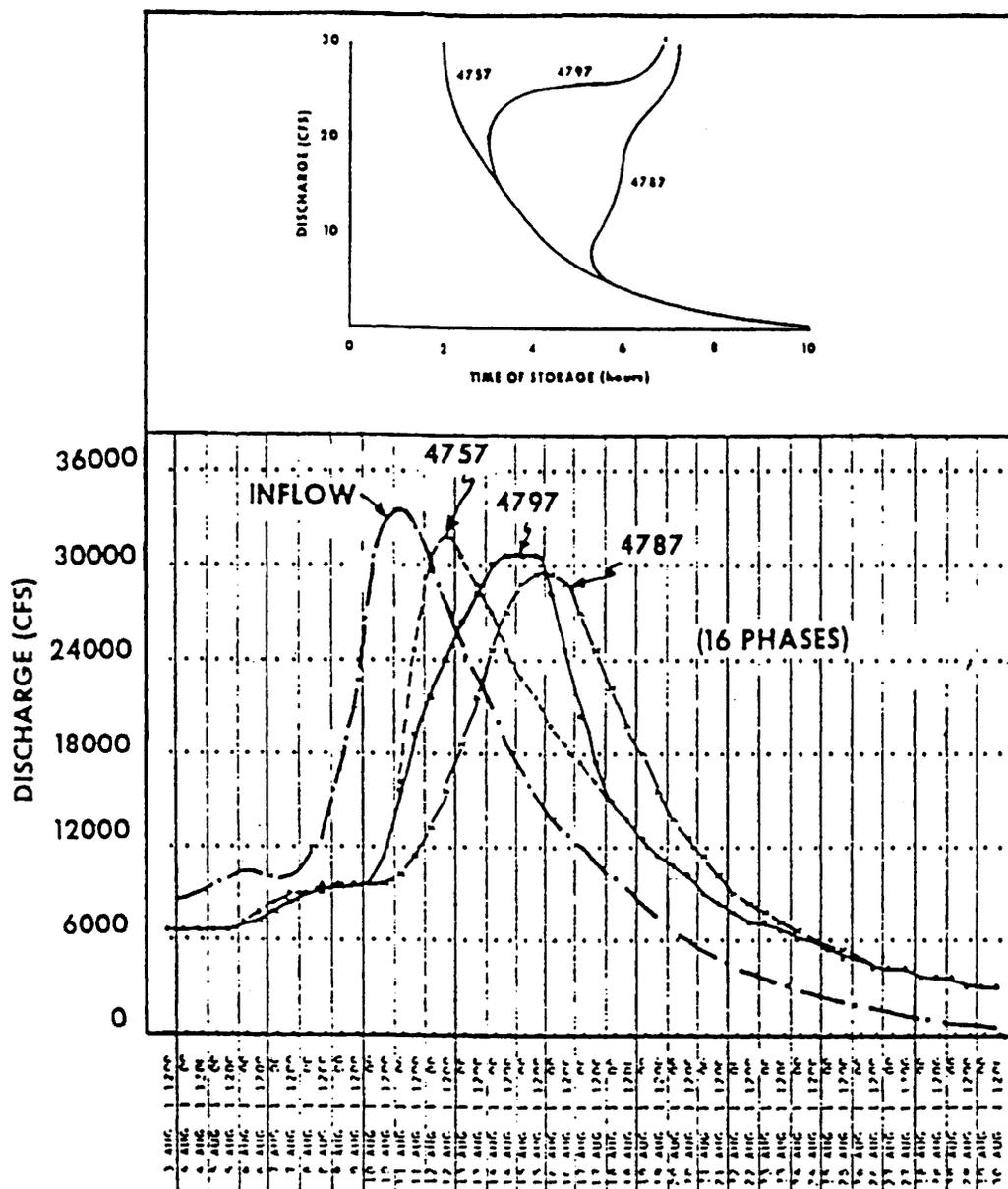


Figure 12. Sample computations for simple single phase route

ASSUME: SINGLE PHASE ROUTE  
 CONSTANT TIME OF STORAGE = 2 HOURS  
 COMPUTATION INTERVAL = 6 HOURS  
 ROUTING EQUATION:

$$O_2 = O_1 + t * (I_m - O_1) / (TS + t/2)$$

Routing period not subdivided:

t = 6 hours  
 TS = 2 hours

$$O_2 = O_1 + 6 * (I_m - O_1) / 5$$

Routing period subdivided:

t = 2 hours  
 TS = 2 hours

$$O_2 = O_1 + 2 * (I_m - O_1) / 3$$

<u>Not Subdivided</u>					<u>Subdivided</u>				
I <sub>1</sub>	I <sub>2</sub>	I <sub>m</sub>	O <sub>1</sub>	O <sub>2</sub>	I <sub>1</sub>	I <sub>2</sub>	I <sub>m</sub>	O <sub>1</sub>	O <sub>2</sub>
					10.0	13.3	11.7	7.0	10.1
					13.3	16.7	15.0	10.1	13.4
10.0	20.0	15.0	7.0	16.6	16.7	20.0	18.4	13.4	16.7
					20.0	25.5	22.8	16.7	20.8
					25.5	30.5	28.0	20.8	25.6
20.0	36.0	28.0	16.6	30.3	30.5	36.0	33.3	25.6	30.7
					36.0	47.2	41.6	30.7	38.0
					47.2	59.0	53.1	38.0	48.1
36.0	70.0	53.0	30.3	57.5	59.0	70.0	64.5	48.1	59.0
					70.0	66.6	68.3	59.0	65.2
					66.6	63.3	65.0	65.2	65.0
70.0	60.0	65.0	57.5	66.5	63.3	60.0	61.7	65.0	62.8
					60.0	51.3	55.7	62.8	58.1
					51.3	43.0	47.2	58.1	50.8
60.0	35.0	47.5	66.5	43.7	43.0	35.0	39.0	50.8	43.0
					35.0	31.6	33.3	43.0	36.5
					31.6	28.3	30.0	36.5	32.2
35.0	25.0	30.0	43.7	27.3	28.3	25.0	26.7	32.2	28.5
					25.0	23.0	24.0	28.5	25.5
					23.0	21.0	22.0	25.5	23.2
25.0	19.0	22.0	27.3	20.9	21.0	19.0	20.0	23.2	21.0

Figure 13. Simple single phase route

